

LINKED SUSPENSION SYSTEM FOR A VEHICLE

Background of the Invention

5 This invention relates to a suspension system suitable for use with a vehicle, and more particularly to a snowmobile track suspension system wherein the front and rear arms of the suspension are coupled such that the position of the front of the track suspension is determined at least in part by the position of the rear of the track suspension.

10 Suspension systems for vehicles are well-known. Generally, suspension systems provide a cushioning effect between the body of the vehicle and the surface on which the vehicle travels. This reduces the unwanted motions produced when the vehicle travels over an irregular surface, thereby enabling greater control and safety of operation, as well as providing a more comfortable ride.

15 Typical suspension systems utilize one or more shock absorbers with springs, hydraulic or pneumatic cylinders, etc., which extend and retract to keep the vehicle in contact with the surface over which it is moving, and which damp themselves to dissipate the energy absorbed in such motion.

Conventional suspension systems may be either unified or independent.

20 Neither type has been entirely satisfactory.

Unified suspension systems utilize a single shock absorber for the vehicle. Unified suspension systems are of only limited value in absorbing unwanted motions. Although they do provide some cushioning, the entire rear suspension is controlled by a single shock absorber. This can cause considerable mechanical stress to

25 both vehicle and passengers, and may result in part of the vehicle losing contact with the surface on which it is traveling.

Independent suspension systems utilize two or more shock absorbers for different parts of the rear suspension. For example, it is known to provide front and rear shock absorbers to control the front and rear halves of a rear suspension separately.

30 Independent suspension systems can absorb motion from uneven terrain more easily,

and are more effective at keeping the vehicle in contact with the surface. However, if one of the shock absorbers is required to retract in order to absorb a large motion while the other is not, the vehicle will naturally pitch. An extreme pitch can result in a harsh ride.

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Summary of the Invention

Therefore it is the purpose of the present invention to overcome the deficiencies of the existing designs. It is the purpose of the present invention to provide a suspension system suitable for use with a vehicle that enables generally independent movement of at least two shock absorbers, but that also provides motive coupling 10 between the shock absorbers, so that under certain circumstances the motion of one shock absorber will produce motion in the other.

An embodiment of a suspension system in accordance with the principles of the present invention comprises first and second shock absorbers connected to a vehicle. The first shock absorber comprises a first main piston, and the second shock 15 absorber comprises a second main piston. The first and second shock absorbers are motivily linked in such a way that when the first main piston retracts, the second main piston also retracts.

It is preferable that the first and second shock absorbers are hydraulic shock absorbers. It is also preferable that the first shock absorber defines a first 20 hydraulic chamber therein, and that the second shock absorber defines a second hydraulic chamber therein, and that the first and second hydraulic chambers are in hydraulic communication, as by a hydraulic line. As the first main piston retracts, the volume of the first hydraulic chamber decreases. This forces part of the volume of the fluid to be transferred to the second hydraulic chamber, which increases the volume of 25 the second hydraulic chamber, which in turn causes the second main piston to retract.

A variety of additional advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed 30 out in the claims. It is to be understood that both the foregoing general description and

the following detailed description are exemplary and explanatory only and are not restrictive of the invention as claimed.

Brief Description of the Drawings

Like reference numbers generally indicate corresponding elements in the 5 figures.

Figure 1 is a perspective view of an embodiment of a suspension system in accordance with the principles of the present invention.

Figure 2 is a schematic view of an embodiment of a suspension system in accordance with the principles of the present invention, wherein the first main piston 10 is in the extended position.

Figure 3 is a schematic view of the embodiment shown in Figure 2, wherein the first main piston is in the retracted position.

Detailed Description of the Preferred Embodiment

Referring to Figure 1, the present invention comprises a suspension 15 system **10** suitable for use with a vehicle. As illustrated, the suspension system **10** is comprised of suspension rails **14** and wheels **16**, as would be suitable for a snowmobile. Details of the drive system, steering system, passenger saddle, etc. are omitted for ease of understanding. It will be apparent to those knowledgeable in the art that the present invention may also be suitable for use with other vehicles, including but not limited to 20 motorcycles, four-wheelers, etc. Suitable vehicles are well-known, and are not described in detail herein.

As may be seen most easily in Figures 2 and 3, the suspension system **10** comprises a first shock absorber **20** and a second shock absorber **30**. It is envisioned that the first shock absorber **20** will be a rear shock absorber controlling and partially 25 supporting the rear of the suspension system **10**, and that the second shock absorber **30** will be a front shock absorber controlling and partially supporting the front of the suspension system **10**. However, it will be apparent to those knowledgeable in the art that such a configuration is exemplary only, and that other configurations may be equally suitable.

The first shock absorber 20 comprises a first body 21 and first main piston 22, the first main piston 22 being moveably disposed within the first body 21. The first main piston 22 is moveable between a retracted position, wherein it is substantially retracted into the first body 21, and an extended position, wherein it is 5 substantially extended from the first body 21.

The second shock absorber 30 comprises a second body 31 and a second main piston 32, the second main piston 32 being moveably disposed within the second body 31. The second main piston 32 is moveable between a retracted position, wherein it is substantially retracted into the second body 31, and an extended position, wherein it 10 is substantially extended from the second body 31.

The first and second shock absorbers 20 and 30 are motively linked with one another such that when the first main piston 22 is moved towards the retracted position, the second main piston 32 is caused to move towards the retracted position.

It will be apparent to those knowledgeable in the art that this 15 configuration of two shock absorbers is exemplary only, and that other numbers of shock absorbers may be equally suitable.

It is preferable that the first and second shock absorbers 20 and 30 are hydraulic shock absorbers, as hydraulic shock absorbers are easily adapted to the needs of the present invention. However, it will be apparent to those knowledgeable in the art 20 that this design is exemplary only, and that other shock absorbers, including but not limited to pneumatic shock absorbers, may be equally suitable.

The first main piston 22 comprises a first main piston head 24 disposed at a first end 26 of the first main piston 22. The first body 21 defines a first hydraulic chamber 28 therein, the first main piston head 24 being movably disposed within the 25 first hydraulic chamber 28. In such a configuration, the volume inside the first hydraulic chamber 28 is smaller when the first main piston 22 is in the retracted position than when the first main piston 22 is in the extended position.

Advantageously, the first main piston head 24 comprises a first damping valve mechanism 25 for enabling fluid flow through the first main piston head 24 in a

controlled manner, so as to minimize cavitation as the first main piston head 24 moves within the first hydraulic chamber 28.

When a first damping valve mechanism 25 is present, it will be appreciated that the first main piston head 24 and the first main piston 22 must be 5 configured relative to the first hydraulic chamber 28 such that fluid within the first hydraulic chamber 28 flows through the first damping valve mechanism 25 of the first main piston head 24 as the first main piston 22 moves between its extended and retracted positions. Advantageously, the first main piston 22, the first main piston head 24, and the first hydraulic chamber 28 are configured such that cavitation within the 10 first hydraulic chamber 28 is avoided or at least minimized as the first main piston 22 and the first main piston head 24 move within the first hydraulic chamber 28.

The second main piston 32 comprises a second main piston head 34 disposed at a first end 36 of the second main piston 32. In the embodiment illustrated, the second shock absorber 30 comprises a separator piston head 38, the separator piston 15 head 38 being moveable independently of the second main piston 32. Advantageously, the separator piston head 38 is moveably disposed on the second main piston 32 proximate the second main piston head 34. The second body 31 and the separator piston head 38 cooperate to define a second hydraulic chamber 40 within the second shock absorber 30. The second shock absorber 30 is configured such that increasing the 20 volume of the second hydraulic chamber 40 causes the separator piston head 38 to press against the second main piston head 34 and/or any hydraulic fluid between the separator piston head 38 and the second main piston head 34, which in turn pushes on the second main piston head 34 thereby causing the second main piston 32 to move toward the retracted position.

25 Advantageously, the second main piston head 34 comprises a second damping valve mechanism 35 for enabling fluid flow through the second main piston head 34 in a controlled manner, so as to minimize cavitation as the second main piston head 34 moves within the third hydraulic chamber 40.

When a second damping valve mechanism 35 is present, it will be 30 appreciated that the second main piston head 34 and the second main piston 32 must be

configured relative to the third hydraulic chamber 40 such that fluid within the third hydraulic chamber 40 flows through the second damping valve mechanism 35 of the second main piston head 34 as the second main piston 32 moves between its extended and retracted positions. Advantageously, the second main piston 32, the second main piston head 34, and the third hydraulic chamber 40 are configured such that cavitation within the third hydraulic chamber 40 is avoided or at least minimized as the second main piston 32 and the second main piston head 34 move within the third hydraulic chamber 40.

10 The first and second hydraulic chambers 28 and 40 may be in hydraulic communication. Hydraulic communication may be made by a first hydraulic line 50.

The first and second hydraulic chambers 28 and 40 are at least substantially filled with a first hydraulic fluid.

15 A variety of fluids may be suitable for use as the first hydraulic fluid. Advantageously, the first hydraulic fluid is a hydraulic oil. More advantageously, the first hydraulic fluid is a synthetic hydraulic oil.

The first hydraulic fluid may be a cavitation-resistant synthetic hydraulic oil. Cavitation is the formation and subsequent collapse of voids or bubbles within a fluid, generally caused by rapid and/or turbulent flow of or motion within the fluid.

20 A variety of suitable oils are available that resist physical and chemical breakdown caused by cavitation, and/or resist cavitation itself. Known cavitation-resistant synthetic oils include but are not limited to Maxima and Amzoil.

Advantageously, the first hydraulic fluid is a medium weight oil.

25 The suspension system 10 may comprise a restrictor 51 disposed between the first and second hydraulic chambers 28 and 40, so as to control fluid flow between the first and second hydraulic chambers 28 and 40. Advantageously, the restrictor 51 is adapted to prevent or at least reduce cavitation of the first hydraulic fluid by controlling the flow of fluid between the first and second hydraulic chambers 28 and 40.

30 Advantageously, the restrictor 51 is disposed in line with the first hydraulic line 50.

A variety of restrictors 51 suitable for use with the suspension system 10 are known, and are not further described herein.

As may be seen in Figures 2 and 3, in such a configuration, when the first main piston 22 is moved toward the retracted position, the volume of the first 5 hydraulic chamber 28 is decreased, whereby the volume of the second hydraulic chamber 40 is increased, whereby the second main piston 32 is caused to move towards the retracted position.

In the configuration illustrated in Figures 2 and 3, the first and second main pistons 22 and 32 may be said to be "in phase". That is, when the first main 10 piston 22 moves towards its retracted position, so does the second main piston 32. The second main piston 32 may undergo substantial independent movement.

In other words, when the first main piston 22 retracts, the second main piston 32 retracts similarly. However, motion of the second main piston 32 does not necessarily cause similar motion of the first main piston 22.

15 The second body 31 and the second main piston head 34 cooperate to define a third hydraulic chamber 42 within the second shock absorber 30.

The third hydraulic chamber 42 is at least substantially filled with a second hydraulic fluid.

A variety of fluids may be suitable for use as the second hydraulic fluid. 20 Advantageously, the second hydraulic fluid is a hydraulic oil. More advantageously, the second hydraulic fluid is a synthetic hydraulic oil.

The second hydraulic fluid may be a cavitation-resistant synthetic hydraulic oil.

25 Advantageously, the second hydraulic fluid is a medium weight oil. It will be apparent to those knowledgeable in the art that this particular configuration of shock absorbers is exemplary only, and that other configurations may be equally suitable.

It will be appreciated that, when the second main piston 32 is in the extended position, the separator piston head 38 is in contact with the extended end 41 of 30 the second hydraulic chamber 40. If the separator piston head 38 and the extended end

41 are configured in such a way as to trap only a thin, uniform film of fluid therebetween when the second main piston 32 is in the extended position, the separator piston head 38 and the extended end 41 may become stuck due to adhesion therebetween via the first hydraulic fluid.

5 Therefore, in an advantageous embodiment the portion of the separator piston 38 that comes in close contact with the extended end 41 has a size and/or shape so as to prevent formation of a thin uniform film of fluid therebetween, and thereby to avoid sticking.

10 In an alternative advantageous embodiment, the second shock absorber 30 comprises an anti-stick mechanism 43 disposed between the separator piston head 38 and the extended end 41. One suitable anti-stick mechanism 43 is a spacer disposed on the second main piston 32. A spacer having a thickness of as little as approximately .040" may be sufficient to prevent sticking. However, it will be appreciated that alternative anti-stick mechanisms may be equally suitable.

15 The second hydraulic chamber 40 may comprise a central portion 44 and a passage portion 46. The central portion 44 is generally adjacent to the third hydraulic chamber 42, the two being separated by the separator piston 38. The passage portion 46 is configured so as to enable a connection 48 for the first hydraulic line 50 to be mounted to the second shock absorber 30 in a convenient position. The passage portion 20 46 and the central portion 44 are in hydraulic communication with one another. This provides a convenient system for delivering the first hydraulic fluid from first hydraulic line 50 to the central portion 44.

Advantageously, the passage portion is configured so as to avoid or at least minimize cavitation of fluid flowing therein.

25 The passage portion 46 may comprise a plurality of holes or tubes disposed peripherally about the central portion 44. In particular, two holes each having a diameter of approximately .160" may be suitable.

Alternatively, a passage portion generally in the shape of a hollow, cylindrical shell may be suitable.

It will be apparent to those knowledgeable in the art that these configurations are exemplary only, and that other configurations may be equally suitable.

It is preferable that the suspension system **10** comprises an adjustor **70** 5 for adjusting the suspension system **10**. The adjustor **70** allows the “trim”, that is, the neutral position of the first and second main pistons, of the suspension system **10** to be set to a desired level.

The adjustor **70** may comprise a adjustor body **71** and an adjustor piston **72**, the adjustor piston **72** being moveably disposed within the adjustor body **71**. The 10 adjustor piston **72** is advantageously moveable between a retracted position, wherein it is substantially retracted into the adjustor body **71**, and an extended position, wherein it is substantially extended from the adjustor body **71**.

The adjustor piston **72** comprises an adjustor piston head **74** at a first end **76** thereof. The adjustor body **71** and the adjustor piston head **74** cooperate to define a 15 fourth hydraulic chamber **78** and a first pneumatic chamber **80** within the adjustor body **71**. As illustrated in Figures 2 and 3, the adjustor **70** is configured such that moving the adjustor piston **72** toward the retracted position causes the volume of the fourth hydraulic chamber **78** to decrease and the volume of the first pneumatic chamber **80** to increase correspondingly, and that moving the adjustor piston **72** toward the extended 20 position causes the volume of the fourth hydraulic chamber **78** to increase and the volume of the first pneumatic chamber **80** to decrease correspondingly. However, this arrangement is exemplary only, and other arrangements may be equally suitable.

In the embodiment illustrated in Figures 2 and 3, decreasing the volume of the fourth hydraulic chamber **78** makes a corresponding additional volume of the first 25 hydraulic fluid available to the first and second hydraulic chambers **28** and **40**. However, a given change in the volume of the first hydraulic chamber **28** causes a change in the position of the first main piston **22** that is greater than the change in position of the second main piston **32** for an equal change in volume of the second hydraulic chamber **40**. Thus, in the embodiment illustrated in Figures 2 and 3, 30 decreasing the volume of the fourth hydraulic chamber **78** causes the second main

piston 32 to move towards its retracted position. This in turn causes the first main piston 22 to move towards its extended position. Conversely, increasing the volume of the fourth hydraulic chamber 78 causes the second main piston 32 to move towards its extended position, which in turn causes the first main piston 22 to move towards its 5 retracted position.

It will be appreciated that this arrangement is exemplary only, and that the motions of the first and second main pistons 32 and 40 in response to a motion of the adjustor piston 72 may be different for other embodiments of the suspension system 10.

10 The fourth hydraulic chamber 78 is in hydraulic communication with at least one of the first hydraulic chamber 28, the second hydraulic chamber 40, and the first hydraulic line 50. Hydraulic communication may be enabled by a second hydraulic line 52. The fourth hydraulic chamber 78 is at least substantially filled with the first hydraulic fluid.

15 The first pneumatic chamber 80 is filled with a first pneumatic fluid. The first pneumatic fluid may be air.

The adjustor piston 72 may comprise adjusting means 82 for enabling convenient adjustment of its position. Suitable adjusting means include but are not limited to screw threads.

20 The adjustor piston 72 may comprise manipulation means 84 for convenient manipulation of the adjustor piston 72. Suitable means include but are not limited to twist knobs, screw heads, and bolt heads.

25 The adjustor piston 72 may comprise locking means 86 for securing the adjusting means 82 so that the adjustor piston 72 may be secured in position when it is not being adjusted. Suitable locking means include but are not limited to locking nuts.

30 It will be apparent to those knowledgeable in the art that this adjustor mechanism is exemplary only, and that suspension systems with other adjustor mechanisms, or no adjustor mechanism, may be equally suitable. In particular, it will be apparent that adjustors without a pneumatic chamber, or having a chamber that is open to the air, may be equally suitable.

It is preferable that the suspension system 10 comprises a remote reservoir mechanism 90 for accommodating motions of the first and second main pistons 22 and 32. As illustrated in Figures 2 and 3, this may be accomplished by accommodating changes in the volumes of the first and second hydraulic chambers 28 and 40.

The remote reservoir mechanism 90 comprises a reservoir body 91 and a remote reservoir piston head 92, the remote reservoir piston head 92 being moveably disposed within the reservoir body 91. The reservoir body 91 and the remote reservoir piston head 92 cooperate to define a fifth hydraulic chamber 94 and a pressure means chamber 96 within the reservoir body 91. The remote reservoir mechanism 90 is configured such that an increase in the volume of the fifth hydraulic chamber 94 causes a corresponding decrease in the volume of the pressure means chamber 96, and that a decrease in the volume of the fifth hydraulic chamber 94 causes a corresponding increase in the volume of the pressure means chamber 96. The relative motions of the fifth hydraulic chamber 94 and the pressure means chamber 96 act to compensate for the changes in volume of the third hydraulic chamber 42, as when the second main piston 32 is retracted, when the volume of the fourth hydraulic chamber 78 in the adjustor 70 changes, or when the volume of the first hydraulic chamber 28 in the first shock absorber 20 changes.

The fifth hydraulic chamber 94 is in hydraulic communication with the third hydraulic chamber 42. Hydraulic communication may be made by a third hydraulic line 54.

The fifth hydraulic chamber 94 is at least substantially filled with the second hydraulic fluid.

The pressure means chamber 96 comprises pressure means 97 therein for exerting pressure against the reservoir piston head 92. A variety of pressure means may be suitable.

In an advantageous embodiment, the pressure means 97 comprises a second pneumatic fluid disposed within the pressure means chamber 96. The second pneumatic fluid is advantageously under sufficient pressure to eliminate or at least

minimize cavitation of the second hydraulic fluid within and proximate to the fifth hydraulic chamber 94. The second pneumatic fluid may be compressed nitrogen. The second pneumatic fluid may alternatively be compressed air.

In another advantageous embodiment, the pressure means 97 comprises a
5 compression spring disposed within the pressure means chamber 96.

It will be apparent to those knowledgeable in the art that this remote reservoir mechanism is exemplary only, and that other remote reservoir mechanisms or no remote reservoir mechanism at all may be equally suitable.

The suspension system 10 may comprise a bleed-back valve 55 disposed
10 between the third and fifth hydraulic chambers 42 and 94, so as to control fluid flow between the third and fifth hydraulic chambers 42 and 94. Advantageously, the bleed-back valve 55 is adapted to adjustably control the flow of fluid between the third and fifth hydraulic chambers 42 and 94. Control of the flow of fluid between the third and fifth hydraulic chambers 42 and 94 affects the rate at which the first and second shock absorbers 20 and 30 "rebound", or return to their original positions.
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Advantageously, the bleed-back valve 55 is disposed in line with the third hydraulic line 54.

Advantageously, the bleed-back valve 55 is adapted to control the flow of fluid between the third and fifth hydraulic chambers 42 and 94 to such a degree that
20 the first and second shock absorbers 20 and 30 provide compressive damping in addition to rebound damping.

A variety of bleed-back valves 55 may be suitable for use with the suspension system 10. For example, a metering rod having a needle and seat arrangement may be suitable. However, bleed-back valves are known, and are not
25 further described herein.

The suspension system 10 may comprise o-rings for sealing various components.

In particular, the separator piston head 38 may comprise an o-ring 39 adapted to prevent fluid flow between the second and third hydraulic chambers 40 and
30 42.

Similarly, the adjustor piston head 74 may comprise an o-ring 75 adapted to prevent fluid flow between the fourth hydraulic chamber 78 and the first pneumatic chamber 80.

5 Likewise, the damping piston head 92 may comprise an o-ring 93 adapted to prevent fluid flow between the fifth hydraulic chamber 94 and the second pneumatic chamber 96.

Additionally, the first shock absorber 20 may comprise an o-ring 23 between the first body 21 and the first main piston 22 to prevent leakage of fluid from the first hydraulic chamber 28.

10 Similarly, the second shock absorber 30 may comprise an o-ring 33 between the second body 31 and the second main piston 32 to prevent leakage of fluid from the second hydraulic chamber 40.

15 Likewise, the adjustor 70 may comprise an o-ring 73 between the adjustor body 71 and the adjustor piston 72 to prevent leakage of fluid from within the adjustor 70.

However, it will be appreciated that these o-rings are exemplary only, and that embodiments lacking any or all, or having additional o-rings, or having o-rings located elsewhere, may be equally suitable.

20 Advantageously, the o-rings 23, 33, 39, 73, 75, and 93 are made of material that resists degradation by the fluids with which they come in contact. For example, when the first and second hydraulic fluids are synthetic oils, the o-rings 23, 33, 39, 73, 75, and 93 advantageously may be made of nitrile or fluoroelastomer. However, a variety of other materials may be equally suitable for use with synthetic oils, and with other fluids.

25 Suitable materials and fittings for shock absorbers beyond those described herein are well known, and are not detailed further herein.

It is noted that, although cavitation is preferably avoided for certain embodiments of the claimed invention, this is exemplary only.

Cavitation is known to contribute to the breakdown of certain hydraulic fluids. It also generally detrimental to the operation of conventional suspension systems.

However, cavitation does not inherently impair the operation of a suspension system 10 in accordance with the principles of the claimed invention. Certain embodiments may be fully operable even under conditions of extreme cavitation.

Furthermore, certain embodiments of a suspension system 10 in accordance with the principles of the claimed invention may derive a positive dynamic effect from cavitation.

The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

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